Ferromagnetic Materials

Advanced

Here is a list of ferromagnetic (including **ferrimagnetic**) materials (from the "Kittel"). Besides the chemical formula, the Curie temperature T_C and the **magnetic moment** m_m of the molecules (in units of the Bohr magneton m_B) is listed

Material	T_C [K]	m_m
Fe	1043	2.22
Co	1388	1.72
Ni	627	0.606
Gd	292	7.63
Dy	88	10.2
CrO_2	386	2.03
MnAs	318	3.4
MnBi	630	3.52 + 3.6 Mn –0.15 Bi
EuO	69	6.8
NiO / Fe (Ferrit)	858	2.4
$Y_3Fe_5O_{12}$	560	5.0

The list could be much longer, but we see a number of interesting facts.

- There exist more *elemental* ferromagnets than just the common trio **Fe**, **Ni**, **Co** - but not at room temperature!
- Elements that do *not* form a ferromagnetic elemental crystal, may become from ferromagnetic crystals in combination with some other atoms. This is especially true for **Mn** and **Cr** compounds.
- There are many "strange" oxides or mixtures of oxides of non-magnetic elements (**EuO**) or magnetic elements that are ferri- or ferromagnetic. Most compounds with the composition $\mathbf{MOFe_2O_3}$ and **M** being some bivalent metal (including **Fe**) are *ferri*magnets.
- The total magnetic moment carried by the atoms or molecules can be rather large; it is a combination of the moments of the atoms (and, if applicable, whatever free electrons contribute). It is constructed from positive and negative contributions for ferrimagnets (as shown for the **MnBi** case), It is, however not obvious, if the total magnetic moment from some compound is "ferro" (all contributions same direction or sign) or "ferri" (different signs). While most oxides are "ferro", some (e.g. $\mathbf{CrBr_3}$, **EuO**, **EuS**) are "ferro".

Here is a list of **anti-ferromagnetic materials**; T_C is now the Néel temperature

Material	T_C [K]
Cr	308
MnO	116
MnS	160
NiO	525
$FeCl_2$	24
FeO	198
$CoCl_2$	25

CoO	291
$NiCl_2$	50

- We find the by now usual suspects **Fe**, **Ni**, **Co**, **Mn**, **Cr** and their oxides, but also plenty of other compounds (mostly not listed).
- While anti-ferromagnetic ordering provides endless challenges for solid state physicists, it appears that there are no practical uses for this magnetic property at present.